

B777 Alerting Issues – Stall

1. Initiating Condition: High altitude airspeed decay with turbulence, autopilot engaged

Type	Alert or cue	Threshold for alert or cue to be presented	Confusion regarding alert or cue	Other issues with regard to alert or cue	When alert is inhibited/suppressed or when cue is masked	How alert or cue is terminated
Visual Alerts	PLI nears/touches airplane symbol on PFD	AOA				Reduction of AOA
	"Airspeed Low" text line on EICAS (precedes stall warning, approximately halfway through amber speed band)	Indicated airspeed below Min Maneuvering Speed (signifying 1.3g maneuver margin to stall); AOA-compensated airspeed, not g-compensated (See B777 FCTM p. 1.6)				Increased airspeed
	Indicated airspeed numerical box turns amber (precedes stall warning)	Indicated airspeed below Min Maneuvering Speed (signifying 1.3g maneuver margin to stall); AOA-compensated airspeed, not g-compensated				Increased airspeed
	When the autopilot is engaged and the aircraft slows to stick shaker speed (assuming autothrottle is not armed or otherwise functional), the autopilot pitch mode reverts to an airspeed mode and the aircraft descends at a speed slightly above stick shaker speed. In this condition an amber line is drawn through the pitch mode on the FMA, the flight director pitch bar is removed from the PFD, and an AUTOPILOT caution is generated on the EICAS	AOA	This autopilot behavior and the associated visual alerts conceivably could be confusing/distracting to the pilot.			Reduction of AOA
Aural Alerts	Stick shaker (sound of)	AOA				Reduction of AOA

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1. Initiating Condition: High altitude airspeed decay with turbulence, autopilot engaged – Cont.

Type	Alert or cue	Threshold for alert or cue to be presented	Confusion regarding alert or cue	Other issues with regard to alert or cue	When alert is inhibited/suppressed or when cue is masked	How alert or cue is terminated
Aural Alerts	Caution alert beeper (precedes stall warning, approximately halfway between min maneuver and stick shaker speeds, associated with Airspeed Low EICAS)	Indicated airspeed below Min Maneuvering Speed (signifying 1.3g maneuver margin to stall); AOA-compensated airspeed, not g-compensated				Increased airspeed
	With autopilot engaged, caution aural beeper is associated with Autopilot EICAS caution, at stick shaker speed.	AOA	As it occurs approximately simultaneously with stick shaker, this caution beeper conceivably could distract from stall identification/recovery			Reduction of AOA
Tactile Alerts	Stick shaker	AOA				Reduction of AOA
Visual Cues	Indicated airspeed at or below red/black band on PFD	Top of red/black airspeed band is g-compensated matching stick shaker AOA				Reduction of AOA
	PFD/ADI indications of uncommanded pitch		Uncommanded pitch/roll and sink rate cues are not normally presented in training, so pilots may be less likely to interpret them as signifying a stall (especially in the absence of stick shaker cues) and also more likely to be distracted by them from stall diagnosis and recovery actions.	To some extent the primary flight computer compensates for the pitch and roll effects of stall. Not all of these control inputs may be back-driven to the control wheel/columns to make the pilots aware of the inputs being required to maintain control of the aircraft.		

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1. Initiating Condition: High altitude airspeed decay with turbulence, autopilot engaged – Cont.

Type	Alert or cue	Threshold for alert or cue to be presented	Confusion regarding alert or cue	Other issues with regard to alert or cue	When alert is inhibited/suppressed or when cue is masked	How alert or cue is terminated
Visual Cues	PFD/ADI indications of uncommanded roll		Uncommanded pitch/roll and sink rate cues are not normally presented in training, so pilots may be less likely to interpret them as signifying a stall (especially in the absence of stick shaker cues) and also more likely to be distracted by them from stall diagnosis and recovery actions.	Note: Bank angle protection is active at 35 degrees bank angle, primary flight computer system attempts to roll back to 30 degrees bank angle. Bank angle indicator turns amber at greater than 35 degrees.		
	PFD/ADI indications of sink rate on vertical speed display		Uncommanded pitch/roll and sink rate cues are not normally presented in training, so pilots may be less likely to interpret them as signifying a stall (especially in the absence of stick shaker cues) and also more likely to be distracted by them from stall diagnosis and recovery actions.			
	Control wheel deflection (autopilot input)			To some extent the primary flight computer compensates for the pitch and roll effects of stall. Not all of these control inputs may be back-driven to the control wheel/columns to make the pilots aware of the inputs being required to maintain control of the aircraft.		
Aural Cues	None					

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1. Initiating Condition: High altitude airspeed decay with turbulence, autopilot engaged – Cont.

Type	Alert or cue	Threshold for alert or cue to be presented	Confusion regarding alert or cue	Other issues with regard to alert or cue	When alert is inhibited/suppressed or when cue is masked	How alert or cue is terminated
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Tactile/ Somatic Cues	Aerodynamic buffet					Reduction of AOA
	In normal flight control mode, when the aircraft slows to near stall speed (approximately halfway through the amber band and same threshold as the "Airspeed Low" EICAS alert), the auto throttles advance to maintain minimum maneuvering speed or the speed set in the MCP command window, whichever is greater	Indicated airspeed below Min Maneuvering Speed (signifying 1.3g maneuver margin to stall); AOA-compensated airspeed, not g-compensated	This autothrottle behavior conceivably could be confusing/distracting to the pilot, although it is certainly useful and desirable in the given condition.			Reduction of AOA

Expected Pilot Response(s)

- Disconnect autopilot and autothrottle
- Apply nose down pitch control until stall warning is eliminated
- Apply nose-down trim as needed
- Roll wings level
- Adjust thrust as needed
- Check speedbrakes retracted
- Return to the desired flightpath

Possible sources of confusion with regard to pilot response(s)

- Autopilot may disconnect while holding wheel input, resulting in rapid roll at the time of disconnection.
- Uncommanded pitch/roll and sink rate cues also can result from other events besides stall, thus not necessarily signaling stall recovery to the pilot. Also these cues can draw the pilot's attention away from stall diagnosis or recovery actions.
- High altitude stall may require greater nose-down input than the stalls trained in the simulator.
- High altitude stall may lead to high speed buffet during recovery, with cues similar to low-speed buffet but different recovery actions required.
- Erroneous pilot inputs (i.e., nose-up pitch inputs) can exacerbate stall or prevent recovery.
 - Note: no salient visual/aural indications of trim motion on this aircraft.

B777 Alerting Issues – Stall

1. Initiating Condition: High altitude airspeed decay with turbulence, autopilot engaged – Cont.

How does pilot know condition is resolved/recovered?

- Cessation of stall warning alerts

Issues with regard to multiple concurrent non-normal conditions

- Condition may devolve to engine surge and/or wing-walking (roll reversals from stall exacerbated by pilot rudder/wheel inputs).
- Possible passenger injuries and aircraft damage.

B777 Alerting Issues – Stall

2. Initiating Condition: Increasing load factor in nose-low, high bank upset, autopilot disengaged

Type	Alert or cue	Threshold for alert or cue to be presented	Confusion regarding alert or cue	Other issues with regard to alert or cue	When alert is inhibited/suppressed or when cue is masked	How alert or cue is terminated
Visual Alerts	PLI nears/touches airplane symbol on PFD	AOA		Pilots do not usually receive simulator training for stall at increased load factor/during roll upset so they are not accustomed to recognizing/reacting to these cues in the stress, novelty, and workload of a roll upset.		Reduction of AOA
	"Airspeed Low" text line on EICAS (may precede stall warning, depending on load factor; approximately halfway through amber speed band)	Indicated airspeed below Min Maneuvering Speed (signifying 1.3g maneuver margin to stall); AOA-compensated airspeed, not g-compensated (See B777 FCTM p. 1.6)		Pilots do not usually receive simulator training for stall at increased load factor/during roll upset so they are not accustomed to recognizing/reacting to these cues in the stress, novelty, and workload of a roll upset.		Increased airspeed
	Red/black airspeed band on PFD rises toward current indicated (centered/boxed) airspeed	Top of red/black airspeed band is g-compensated matching stick shaker AOA		Pilots do not usually receive simulator training for stall at increased load factor/during roll upset so they are not accustomed to recognizing/reacting to these cues in the stress, novelty, and workload of a roll upset.		Reduction of AOA

B777 Alerting Issues – Stall

2. Initiating Condition: Increasing load factor in nose-low, high bank upset, autopilot disengaged – Cont.

Type	Alert or cue	Threshold for alert or cue to be presented	Confusion regarding alert or cue	Other issues with regard to alert or cue	When alert is inhibited/suppressed or when cue is masked	How alert or cue is terminated
Visual Alerts	Indicated airspeed numerical box turns amber (may precede stall warning, depending on load factor)	Indicated airspeed below Min Maneuvering Speed (signifying 1.3g maneuver margin to stall)); AOA-compensated airspeed, not g-compensated		Pilots do not usually receive simulator training for stall at increased load factor/during roll upset so they are not accustomed to recognizing/reacting to these cues in the stress, novelty, and workload of a roll upset.		Increased airspeed
	PFD bank angle indicator turns amber	Bank angle >35 degrees		This is not an alert to the stall, but rather to the excessive bank angle from the roll upset		Reduction of bank angle
Aural Alerts	Stick shaker (sound of)	AOA		Pilots do not usually receive simulator training for stall at increased load factor/during roll upset so they are not accustomed to recognizing/reacting to these cues in the stress, novelty, and workload of a roll upset.		Reduction of AOA
	Caution alert beeper (approximately halfway between min maneuver and stick shaker speeds, associated with Airspeed Low EICAS; may precede stall warning depending on load factor)	Indicated airspeed below Min Maneuvering Speed (signifying 1.3g maneuver margin to stall)); AOA-compensated airspeed, not g-compensated		Pilots do not usually receive simulator training for stall at increased load factor/during roll upset so they are not accustomed to recognizing/reacting to these cues in the stress, novelty, and workload of a roll upset.		
	GPWS 'Bank Angle'	Bank angle >35, 40, and 45 degrees		This is not an alert to the stall, but rather to the excessive bank angle from the roll upset.		Reduction of bank angle

B777 Alerting Issues – Stall

2. Initiating Condition: Increasing load factor in nose-low, high bank upset, autopilot disengaged – Cont.

Type	Alert or cue	Threshold for alert or cue to be presented	Confusion regarding alert or cue	Other issues with regard to alert or cue	When alert is inhibited/suppressed or when cue is masked	How alert or cue is terminated
Tactile Alerts	Stick shaker	AOA		Pilots do not usually receive simulator training for stall at increased load factor/during roll upset so they are not accustomed to recognizing/reacting to these cues in the stress, novelty, and workload of a roll upset.		Reduction of AOA
Visual Cues	Indicated airspeed at or below red/black band on PFD	Top of red/black airspeed band is g-compensated matching stick shaker AOA		Pilots do not usually receive simulator training for stall at increased load factor/during roll upset so they are not accustomed to recognizing/reacting to these cues in the stress, novelty, and workload of a roll upset.		Reduction of AOA
	PFD/ADI indications of uncommanded pitch		Uncommanded pitch/roll and sink rate cues from stall are extremely difficult to isolate and identify during a dynamic roll upset, so pilots may be very unlikely to interpret them as signifying a stall (especially in the absence of stick shaker cues).	Pilots do not usually receive simulator training for stall at increased load factor/during roll upset so they are not accustomed to recognizing/reacting to these cues in the stress, novelty, and workload of a roll upset.		

B777 Alerting Issues – Stall

2. Initiating Condition: Increasing load factor in nose-low, high bank upset, autopilot disengaged – Cont.

Type	Alert or cue	Threshold for alert or cue to be presented	Confusion regarding alert or cue	Other issues with regard to alert or cue	When alert is inhibited/suppressed or when cue is masked	How alert or cue is terminated
Visual Cues	PFD/ADI indications of uncommanded roll		Uncommanded pitch/roll and sink rate cues from stall are extremely difficult to isolate and identify during a dynamic roll upset, so pilots may be very unlikely to interpret them as signifying a stall (especially in the absence of stick shaker cues).	Pilots do not usually receive simulator training for stall at increased load factor/during roll upset so they are not accustomed to recognizing/reacting to these cues in the stress, novelty, and workload of a roll upset.		
	PFD/ADI indications of sink rate on vertical speed display		Uncommanded pitch/roll and sink rate cues from stall are extremely difficult to isolate and identify during a dynamic roll upset, so pilots may be very unlikely to interpret them as signifying a stall (especially in the absence of stick shaker cues).	Pilots do not usually receive simulator training for stall at increased load factor/during roll upset so they are not accustomed to recognizing/reacting to these cues in the stress, novelty, and workload of a roll upset.		
Aural Cues	Wind noise		Wind noise is not a reliable cue to angle-of-attack, but loud wind noise may potentially mislead pilots into thinking they are not stalling during a high-speed stall			
Tactile/Somatic Cues	Aerodynamic Buffet	AOA (natural)		Pilots do not usually receive simulator training for stall at increased load factor/during roll upset so they are not accustomed to recognizing/reacting to these cues in the stress, novelty, and workload of a roll upset.		

B777 Alerting Issues – Stall

2. Initiating Condition: Increasing load factor in nose-low, high bank upset, autopilot disengaged – Cont.

Type	Alert or cue	Threshold for alert or cue to be presented	Confusion regarding alert or cue	Other issues with regard to alert or cue	When alert is inhibited/ suppressed or when cue is masked	How alert or cue is terminated
Tactile/ Somatic Cues	In normal flight control mode, nose-up trim is inhibited at min maneuvering speed, requiring increasing aft column force by the pilot to slow the aircraft into the stall region (when hand flown). This occurs approximately simultaneously with the "autothrottle wake-up."	Indicated airspeed below Min Maneuvering Speed (signifying 1.3g maneuver margin to stall); AOA-compensated airspeed, not g-compensated				
	In normal flight control mode, when bank angle exceeds 35 degrees, the aircraft automatically applies control wheel forces to attempt to restore a 30 degree bank angle. This will present to the pilot as wheel force (can be overridden) and anti-roll wheel deflection.	Bank angle >35 degrees	In this regard the aircraft behaves differently than a non-fly-by-wire aircraft, which may confuse the pilots.			

Expected Pilot Response(s)

- Disconnect autopilot and autothrottle
- Apply nose down pitch control until stall warning is eliminated
- Apply nose-down trim as needed
- Roll wings level
- Adjust thrust as needed
- Check speedbrakes retracted
- Return to the desired flightpath

Possible sources of confusion with regard to pilot response(s)

- Stall in nose-low condition (or devolving to nose-low condition) can require counter-intuitive pitch-down control inputs.
- If terrain proximity, the pilot may have to pitch down while being presented with a "Pull Up" GPWS warning.
- Erroneous pilot inputs (i.e., nose-up pitch inputs) can exacerbate stall or prevent recovery.

B777 Alerting Issues – Stall

2. Initiating Condition: Increasing load factor in nose-low, high bank upset, autopilot disengaged – Cont.

How does pilot know condition is resolved/recovered?

- Termination of stall warning alerts.

Issues with regard to multiple concurrent non-normal conditions

- Recovery from stall condition must be followed immediately by recovery from nose-low, high bank upset condition.
- Possible passenger injuries and aircraft damage.

B777 Alerting Issues – Stall

3. Initiating Condition: Wing ice accumulation

Type	Alert or cue	Threshold for alert or cue to be presented	Confusion regarding alert or cue	Other issues with regard to alert or cue	When alert is inhibited/suppressed or when cue is masked	How alert or cue is terminated
Visual Alerts	None: PLI is present but may not be touching the aircraft symbol when the stall occurs (suggesting to the pilot that the aircraft is not stalling)		The expected alerts and cues will be absent		Alerts and cues are masked by the icing condition which causes the aircraft to stall at lower-than-normal AOA	
Aural Alerts	None		The expected alerts and cues will be absent		Alerts and cues are masked by the icing condition which causes the aircraft to stall at lower-than-normal AOA	
Tactile Alerts	None		The expected alerts and cues will be absent	Pilots are trained extensively to associate stick shaker as trigger to stall recovery; in absence of stick shaker (warning system failure or stall at lower-than-nominal AOA) they may not interpret the secondary cues of buffet, roll, etc. as being related to stall.	Alerts and cues are masked by the icing condition which causes the aircraft to stall at lower-than-normal AOA	
Visual Cues	None: airspeed appears to be adequate but is not; airplane may stall while indicated airspeed is in the amber band but not in or touching the red/black band		The expected alerts and cues will be absent		Alerts and cues are masked by the icing condition which causes the aircraft to stall at lower-than-normal AOA	
	PFD/ADI indications of uncommanded pitch		In the absence of the expected, salient alerts, these cues may not be interpreted as being related to stall			

B777 Alerting Issues – Stall

3. Initiating Condition: Wing ice accumulation – Cont.

Type	Alert or cue	Threshold for alert or cue to be presented	Confusion regarding alert or cue	Other issues with regard to alert or cue	When alert is inhibited/suppressed or when cue is masked	How alert or cue is terminated
Visual Cues	PFD/ADI indications of uncommanded roll		In the absence of the expected, salient alerts, these cues may not be interpreted as being related to stall			
	PFD/ADI indications of sink rate on vertical speed display		In the absence of the expected, salient alerts, these cues may not be interpreted as being related to stall			
Aural Cues	None		The expected alerts and cues will be absent		Alerts and cues are masked by the icing condition which causes the aircraft to stall at lower-than-normal AOA	
Tactile/ Somatic Cues	Aerodynamic Buffet; unusual wheel/column forces (autopilot off) or displacements (autopilot on)	AOA (natural)	In the absence of the expected, salient alerts, these cues may not be interpreted as being related to stall			Reduction of AOA

Expected Pilot Response(s)

- Disconnect autopilot and autothrottle
- Apply nose down pitch control until stall warning is eliminated
- Apply nose-down trim as needed
- Roll wings level
- Adjust thrust as needed
- Check speedbrakes retracted
- Return to the desired flightpath

B777 Alerting Issues – Stall

3. Initiating Condition: Wing ice accumulation – Cont.

Possible sources of confusion with regard to pilot response(s)

- In the absence of the usual salient alerts, the pilots may not realize that the aircraft is stalled.
- Erroneous pilot inputs (i.e., nose-up pitch inputs) can exacerbate stall or prevent recovery.

How does pilot know condition is resolved/recovered?

- Difficult to know, related to cessation of uncommanded pitch/roll/sink.

Issues with regard to multiple concurrent non-normal conditions

- Condition may devolve to engine surge and/or wing-walking (roll reversals from stall exacerbated by pilot rudder/wheel inputs).
- Possible passenger injuries and aircraft damage.

B777 Alerting Issues – Stall

4. Initiating Condition: False stall warning during takeoff rotation

Type	Alert or cue	Threshold for alert or cue to be presented	Confusion regarding alert or cue	Other issues with regard to alert or cue	When alert is inhibited/suppressed or when cue is masked	How alert or cue is terminated
Visual Alerts	PLI touches airplane symbol on PFD (false indication)	AOA	Conflict between highly salient, but false alerts and subtle, valid cues: Salient alerts that the airplane is stalled must be compared with normal rotation/climb performance under extreme time pressure, and ignored.		Inhibition/suppression not relevant because the alert is false	Alert or cue is not terminated as it is invalid
Aural Alerts	Stick shaker, sound of (false indication)	AOA	Conflict between highly salient, but false alerts and subtle, valid cues: Salient alerts that the airplane is stalled must be compared with normal rotation/climb performance under extreme time pressure, and ignored.		Inhibition/suppression not relevant because the alert is false	Alert or cue is not terminated as it is invalid
Tactile Alerts	Stick shaker (false indication)	AOA	Conflict between highly salient, but false alerts and subtle, valid cues: Salient alerts that the airplane is stalled must be compared with normal rotation/climb performance under extreme time pressure, and ignored.		Inhibition/suppression not relevant because the alert is false	Alert or cue is not terminated as it is invalid
Visual Cues	Normal vertical speed, altimeter, and airspeed indications on PFD, as well as view through the windshield of the aircraft climbing (if VMC) are subtle cues that the aircraft is not stalling		Conflict between highly salient, but false alerts and subtle, valid cues: Salient alerts that the airplane is stalled must be compared with normal rotation/climb performance under extreme time pressure, and ignored.			
Aural Cues	None					
Tactile/Somatic Cues	Normal vertical acceleration from rotation into climb is a subtle cue that the aircraft is not stalling		Conflict between highly salient, but false alerts and subtle, valid cues: Salient alerts that the airplane is stalled must be compared with normal rotation/climb performance under extreme time pressure, and ignored.			

B777 Alerting Issues – Stall

4. Initiating Condition: False stall warning during takeoff rotation – Cont.

Expected Pilot Response(s)

- Ignore false alerts and cues.
- Do not reject takeoff.

Possible sources of confusion with regard to pilot response(s)

- Conflict between highly salient, but false alerts and subtle, valid cues: Salient alerts that the airplane is stalled must be compared with normal rotation/climb performance under extreme time pressure, and ignored.
- Pilots are trained to respond to stall warnings/alerts immediately and without deliberation, decreasing the likelihood of identifying the false warning through effortful analysis and suppressing the reaction to the false warning.
- Split-second decision to perform a late rejection or continue.

How does pilot know condition is resolved/recovered?

- Observe normal takeoff and climb performance.

Issues with regard to multiple concurrent non-normal conditions

- None unless pilot takes unneeded actions, such as high speed RTO.